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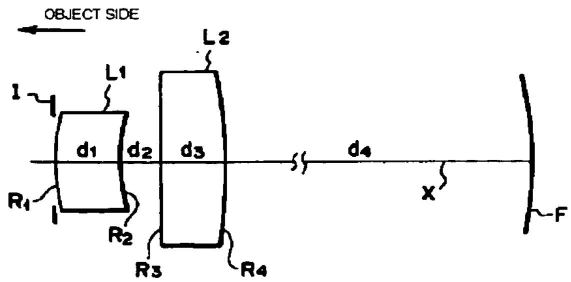
(54) **[Title of the Invention]** WIDE-ANGLE LENS FOR A CAMERA

(57) **[Abstract]**

[Objects] A wide-angle lens for a camera is built so as to have a front-aperture, two-lens-element construction and fulfill four prescribed conditional formulae. This helps reduce the total length of the lens and facilitate the assembly thereof. It is also possible to simplify the construction of the lens, reduce the manufacturing cost thereof, and enhance the imaging performance thereof.

[Features] A wide-angle lens for a camera is built by arranging, from the object side, an aperture stop I, a first lens element L_1 having a negative refractive power, and a second lens element L_2 having a positive refractive power. The first lens element L_1 is a negative meniscus lens element convex to the object side, and the second lens element L_2 is a biconvex lens element having a sharp-curvature surface facing film F. Here, f_2 / f_1 is set equal to

-0.0860, f / R_1 equal to 6.1160, f / R_3 equal to 0.1635, D / f equal to 0.1200, the lens total length equal to 33.471 mm, and the telephoto ratio equal to 1.031.



[Claims]

[Claim 1] A wide-angle lens for a camera which is built by arranging, from an object side, a brightness aperture stop, a first lens element L_1 composed of a positive or negative meniscus lens element convex to the object side, and a second lens element L_2 composed of a positive lens element, and that fulfills the following conditional formulae (1) to (4):

(1) $-0.10 < f_2 / f_1 < 0.7$

(2) $4.0 < f / R_1 < 7.5$

(3) $0 < f / R_3 < 1.6$

(4) $0.10 < D / f < 0.22$

where f_1 represents a focal length of the first lens element L_1,

f_2 represents a focal length of the second lens element L_2,

R_1 represents a paraxial radius of curvature of the object-side surface of the first lens element L_1,

R_3 represents a paraxial radius of curvature of the object-side surface of the second lens element L_2, and

D represents a distance from the object-side surface of the first lens element L_1 to the imaging-surface-side surface of the second lens element L_2.

[Claim 2] A wide-angle lens for a camera as claimed in claim 1, wherein the first and second lens elements L_1 and L_2 are both plastic lens elements.

[Claim 3] A wide-angle lens for a camera as claimed in claim 1 or 2, wherein at least one of lens surfaces of the first and second lens elements L_1 and L_2 is an aspherical surface.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an inexpensive, simple wide-angle lens for a camera which is suitable for use in a still camera or electronic still camera, and more particularly to a wide-angle lens for a camera which is composed of two lens elements and a brightness aperture stop.

[0002]

[Prior Art] As wide-angle lenses for use in still cameras and electronic still cameras, there are conventionally known many that are of the so-called between-the-lens aperture type, in which a brightness aperture stop is sandwiched between two convex lens elements.

[0003] Many wide-angle lenses of the between-the-lens aperture type are constructed symmetrically, which helps obtain good imaging performance and excellent wide-angle

functions.

[0004]

[Problems to be Solved by the Invention] However, wide-angle lenses of the between-the-lens aperture type described above have the disadvantage that their total lens length, i.e., the length from the front lens surface of the lens system to the imaging surface, is unduly great, and this makes them difficult to assemble. In particular, in modern easy-to-use cameras that are expected to be slim and compact, greater total lens lengths are best avoided.

[0005] The present invention has been devised to overcome those problems, and its object is to provide a wide-angle lens for a camera which is inexpensive and simple in construction but which nevertheless offers satisfactory imaging performance, and which has a compact optical system and is easy to assemble as a result of reducing the total lens length, i.e. the length from the front lens surface of the lens system to the imaging surface.

[0006]

[Means for Solving the Problem] A wide-angle lens for a camera according to the invention is built by arranging, from the object side, a brightness aperture stop, a first lens element L_1, and a second lens element L_2. That is, it is built so as to have a front-aperture, two-lens-element construction. This helps reduce the total lens length. Moreover, to obtain satisfactory imaging performance in this front-aperture, two-lens-element construction, the wide-angle lens is built so as to fulfill four conditional formulae.

[0007] Specifically, a wide-angle lens for a camera according to the invention is built by arranging, from the object side, a brightness aperture stop, a first lens element L_1 composed of a positive or negative meniscus lens element convex to the object side, and a second lens element L_2 composed of a positive lens element, and fulfills the following conditional formulae (1) to (4):

[0008] (1) $-0.10 < f_2 / f_1 < 0.7$

(2) $4.0 < f / R_1 < 7.5$

(3) $0 < f / R_3 < 1.6$

(4) $0.10 < D / f < 0.22$

where f_1 represents the focal length of the first lens element L_1,

f_2 represents the focal length of the second lens element L_2,

R_1 represents the paraxial radius of curvature of the object-side surface of the first lens element L_1,

R_3 represents the paraxial radius of curvature of the object-side surface of the second lens element L_2, and

D represents the distance from the object-side surface of the first lens element L_1 to the imaging-surface-side surface of the second lens element L_2.

Here, it is preferable that the two lens elements L_1 and L_2 be formed of plastic.

[0009] It is preferable that at least one of the lens surfaces of the two lens elements L_1 and L_2 be an aspherical surface.

[0010] The position at which the brightness aperture stop is disposed may coincide with the position of the object-side lens surface of the first lens element L_1.

[0011]

[Working] The construction described above is a front-aperture, two-lens-element construction; that is, in a lens system consisting of a first lens element L_1 composed of a positive or negative meniscus lens element convex to the object side and a subsequent second lens element L_2 composed of a positive lens element, a brightness aperture stop is disposed at the position of the object-side lens surface of the first lens element L_1 or on the object side thereof. This makes it possible to reduce, in a simple construction, the total lens length, i.e., the length from the front lens surface of the lens system to the imaging surface, and thereby make the optical system compact and easy to assemble.

[0012] Conditional formula (1) noted above relates to the distribution of refractive powers between the first and second lens elements L_1 and L_2. When conditional formula (1), which defines the appropriate distribution, is fulfilled, it is possible to obtain simultaneously a satisfactory lens total length and satisfactory imaging performance.

[0013] Specifically, transgressing the lower limit of conditional formula (1) results in the second lens element L_2 having an excessively strong refractive power, leading to large spherical aberration, curvature of field, and distortion.

[0014] Even if conditional formula (1) is not fulfilled, it is possible to reduce spherical aberration and curvature of field to a certain degree by using an aspherical surface or by giving the film surface a curvature. This, however, results in larger distortion and a greater lens total length, which are undesirable.

[0015] Transgressing the upper limit of conditional formula (1) helps reduce the total lens length, but results in too large lateral chromatic aberration and astigmatism to be corrected even by giving the film surface a curvature.

[0016] Conditional formulae (2) and (3) noted above relate to the shapes of the lens elements that, when conditional formula (1) is already fulfilled, help improve the lens total length and imaging performance simultaneously.

[0017] Transgressing the lower limit of conditional formula (2) helps make spherical

aberration acceptably small, but results in an unduly great lens total length or unduly large curvature of field. By contrast, transgressing the upper limit helps reduce the lens total length and make curvature of field acceptably small, but results in larger spherical aberration and coma.

[0018] Transgressing the lower limit of conditional formula (3) results in an unduly great total lens length and in the second lens element L_2 having too sharp a curvature on its rear surface, adversely affecting spherical aberration. By contrast, transgressing the upper limit results in larger lateral chromatic aberration.

[0019] Conditional formula (4) noted above relates to the lens length D. Transgressing the upper limit results in the second lens element L_2 having an unduly large external diameter, making it impossible to make the optical system compact. Transgressing the lower limit results in the first and second lens elements L_1 and L_2 having insufficient center thicknesses or in an insufficient distance between the first and second lens elements L_1 and L_2, and may result in insufficient correction of curvature of field.

[0020] By forming the first and second lens elements L_1 and L_2 out of plastic, it is possible to reduce the manufacturing costs of the lens system.

[0021] By making at least one of the lens surfaces of the first and second lens elements L_1 and L_2 aspherical, it is possible to achieve a wide angle and high performance simultaneously in a two-lens-element construction. That is, as opposed to the between-the-lens aperture type described earlier as prior art, in a lens system like that of the invention in which an aperture stop is placed at the front and the shapes of the two lens elements L_1 and L_2 greatly differ from each other, the wider-angle the optical system is made, distortion and other aberrations inevitably tend to increase. Thus, it is preferable to use an aspherical lens surface to overcome the demerits ascribable to the asymmetry of the lens system.

[0022]

[Examples of the Invention] Hereinafter, examples of the invention will be described with reference to the drawings.

[0023] Figs. 1 to 4 are respectively sectional views of lens systems embodying the invention, each having values set specifically as shown in Table 1 below. In the table, the following symbols are used:

[0024] f_1 represents the focal length of the first lens element L_1,

f_2 represents the focal length of the second lens element L_2,

f represents the focal length of the entire lens system,

R_1 represents the paraxial radius of curvature of the object-side surface of the first lens

element L_1,

R_3 represents the paraxial radius of curvature of the object-side surface of the second lens element L_2,

D represents the distance from the object-side surface of the first lens element L_1 to the imaging-surface-side surface of the second lens element L_2, and

L represents the total lens length (the distance form the object-side surface of the first lens element L_1 to the imaging surface).

[0025]

[Table 1]

	Example 1	Example 2	Example 3	Example 4
f_2 / f_1	–0.0860	0.5051	0.5794	0.2933
f / R	6.1160	5.6995	5.8289	4.7367
f / R_3	0.1635	0.6673	1.4245	1.5070
D / f	0.1200	0.1842	0.1836	0.1950
L (mm)	33.471	26.011	25.245	24.417
L / f (telephoto ratio)	1.031	1.023	1.010	1.017

[0026] Fig. 1 is a sectional view of the wide-angle lens of Example 1 for a camera. This wide-angle lens is built by arranging, from the object side, an aperture stop I, a first lens element L_1 having a negative refractive power, and a second lens element L_2 having a positive refractive power. Here, the first lens element L_1 is a negative meniscus lens element convex to the object side, and the second lens element L_2 is a biconvex lens element having a sharp-curvature surface facing the film F (i.e., the imaging surface; this applies also in the following examples). The first lens element L_1 has a focal length f_1 of –312.24 mm, the second lens element L_2 has a focal length f_2 of 26.85 mm, and the composite focal length f of the lens system as a whole is 32.47 mm. The back focal length l is 29.571 mm, and the film F has a curvature of which the radius of curvature r is –100.0 mm. The aperture stop I is placed on the object-side surface of the first lens element L_1 (hereinafter referred to as the first surface), and the angle of view 2ω is set equal to 67.4°. In the figure, X represents the optical axis (this applies also in Figs. 2, 3, and 4).

[0027] The two lens elements L_1 and L_2 are formed of plastic. This applies also in the following examples.

[0028] Table 2 below shows the radius of curvature R (mm) near the optical axis X of each lens surface, the center thickness of each lens element, the aerial distance d (mm) between the lens elements, and the refractive index N for the d-line and the Abbe number ν of each lens

element as observed in Example 1.

[0029] In Table 2, the numbers with which the symbols R, d, N, and ν are suffixed represent the order from the object side.

[0030] The object-side surfaces of the first and second lens elements L_1 and L_2 are aspherical surfaces, of which the shape is expressed by the aspherical surface formula

[0031]

[Formula 1]

$$X = \frac{CY^2}{1+\sqrt{1-KC^3Y^2}} + a_1Y^4 + a_2Y^6 + a_3Y^8 + a_4Y^{10}$$

[0032] using, as the coefficients C, K, a_1, a_2, a_3, and a_4, values shown in Table 3 below. In the aspherical surface formula above, X represents the distance from the lens surface along the optical axis X, Y represents the distance from the optical axis X in the vertical direction, and C represents the curvature.

[0033]

[Table 2]

R	d	N	ν
5.309*1	1.50	1.49116	57.8
4.654	0.90		
198.555*2	1.50	1.49116	57.8

[0034]

[Table 3]

Surface	Surface 1	Surface 3
C	0.188359	0.005036
K	7.44698	3674.719
a_1	-0.637315×10^{-2}	0.781309×10^{-3}
a_2	0.968608×10^{-4}	0.141142×10^{-3}
a_3	-0.571697×10^{-3}	-0.548809×10^{-5}
a_4	0.0	0.0

[0035] Fig. 2 is a sectional view of the wide-angle lens of Example 2 for a camera. This wide-angle lens is built by arranging, from the object side, an aperture stop I, a first lens element L_1 having a positive refractive power, and a second lens element L_2 having a positive refractive power. Here, the first lens element L_1 is a positive meniscus lens element convex to the object side, and the second lens element L_2 is a biconvex lens element having a sharp-

curvature surface facing the film F. The first lens element L_1 has a focal length f_1 of 68.52 mm, the second lens element L_2 has a focal length f_2 of 34.61 mm, and the composite focal length f of the lens system as a whole is 25.30 mm. The back focal length l is 21.351 mm, and the film F has a curvature of which the radius of curvature r is –100.0 mm. The aperture stop I is placed on the first surface, and the angle of view 2ω is set equal to 74.5°.

[0036] Table 4 below shows the radius of curvature R (mm) near the optical axis X of each lens surface, the center thickness of each lens element, the aerial distance d (mm) between the lens elements, and the refractive index N for the d-line and the Abbe number ν of each lens element as observed in Example 2.

[0037] Table 5 below shows the values of the coefficients C, K, a_1, a_2, a_3, and a_4 used in the aspherical surface formula noted earlier as observed in Example 2.

[0038] The numbers with which the symbols are suffixed are the same as in Tables 2 and 3.

[0039]

[Table 4]

R	d	N	ν
4.439	1.40	1.49244	57.6
4.580	1.66		
37.913	1.60	1.49244	57.6
–30.538*1			

[0040]

[Table 5]

Surface	Surface 4
C	–0.032746
K	1.00
a_1	0.2645396×10^{-3}
a_2	-0.193124×10^{-4}
a_3	0.129464×10^{-6}
a_4	0.807664×10^{-9}

[0041] Fig. 3 is a sectional view of the wide-angle lens of Example 3 for a camera. This wide-angle lens is built by arranging, from the object side, an aperture stop I, a first lens element L_1 having a positive refractive power, and a second lens element L_2 having a positive refractive power. Here, the first and second lens elements L_1 and L_2 are both positive meniscus lens elements convex to the object side. The first lens element L_1 has a focal length f_1 of 62.89 mm, the second lens element L_2 has a focal length f_2 of 36.44 mm, and the

composite focal length f of the lens system as a whole is 25.00 mm. The back focal length l is 20.655 mm, and the film F has a curvature of which the radius of curvature r is –85.0 mm. The aperture stop I is placed on the object side of the first surface at 3.0 mm therefrom, and the angle of view 2ω is set equal to 75.2°.

[0042] Table 6 below shows the radius of curvature R (mm) near the optical axis X of each lens surface, the center thickness of each lens element, the aerial distance d (mm) between the lens elements, and the refractive index N for the d-line and the Abbe number ν of each lens element as observed in Example 3.

[0043] The numbers with which the symbols are suffixed are the same as in Tables 2 and 3.

[0044] Table 7 below shows the values of the coefficients C, K, a_1, a_2, a_3, and a_4 used in the aspherical surface formula noted earlier as observed in Example 3.

[0045]

[Table 6]

R	d	N	ν
4.289	1.30	1.49244	57.6
4.481	1.39		
17.550	1.90	1.49244	57.6
767.040*1			

[0046]

[Table 7]

Surface	Surface 4
C	0.0013037
K	–71158.06
a_1	0.762047×10^{-3}
a_2	-0.610663×10^{-4}
a_3	0.316390×10^{-5}
a_4	-0.798321×10^{-7}

[0047] Fig. 4 is a sectional view of the wide-angle lens of Example 4 for a camera. This wide-angle lens is built by arranging, from the object side, an aperture stop I, a first lens element L_1 having a positive refractive power, and a second lens element L_2 having a positive refractive power. Here, the first lens element L_1 is a positive meniscus lens element convex to the object side, and the second lens element L_2 is a biconvex lens element having a sharp-curvature surface facing the object side. The first lens element L_1 has a focal length f_1 of 95.19 mm, the second lens element L_2 has a focal length f_2 of 27.92 mm, and the composite

focal length f of the lens system as a whole is 24.00 mm. The back focal length l is 19.737 mm, and the film F has a curvature of which the radius of curvature r is –90.0 mm. The aperture stop I is placed on the first surface, and the angle of view 2ω is set equal to 77.5°.

[0048] Table 8 below shows the radius of curvature R (mm) near the optical axis X of each lens surface, the center thickness of each lens element, the aerial distance d (mm) between the lens elements, and the refractive index N for the d-line and the Abbe number ν of each lens element as observed in Example 4.

[0049] Table 9 below shows the values of the coefficients C, K, a_1, a_2, a_3, and a_4 used in the aspherical surface formula noted earlier as observed in Example 4.

[0050] The numbers with which the symbols are suffixed are the same as in Tables 2 and 3.

[0051]

[Table 8]

R	D	N	ν_d
5.067	1.82	1.49244	57.6
5.006*1	0.88		
15.926	1.98	1.49244	57.6
-96.500*2			

[0052]

[Table 9]

Surface	Surface 2 (*1)	Surface 4 (*2)
C	0.199760	–0.010363
K	–1.191124	-1.585373×10^{4}
a_1	-0.458142×10^{-3}	0.413083×10^{-3}
a_2	0.124943×10^{-2}	-0.143931×10^{-4}
a_3	-0.201013×10^{-3}	-0.298829×10^{-6}
a_4	0.626807×10^{-16}	-0.792994×10^{-14}

[0053] Fig. 5 shows aberration diagrams (one for spherical aberration and sine condition, another for curvature of field, and still another for distortion; this applies also to the following figures) of Example 1, Fig. 6 shows aberration diagrams of Example 2, and Fig. 7 shows aberration diagrams of Fig. 8.

[0054] According to the examples described above, it is possible to realize a compact, high-performance, inexpensive wide-angle lens that offers a telephoto ratio of 1.0 to 1.03 and a practically sufficient angle of view of about 67° to 78°.

[0055] A wide-angle lens embodying the invention may be constructed in any other manner than specifically described above as four examples, and many variations and modifications are possible. For example, although in the examples described above the film F, which serves as the imaging surface, is given a curvature to improve curvature of field and distortion, it is also possible to use flat film F as the imaging surface in a wide-angle lens according to the invention.

[0056] Needless to say, the two lens elements L_1 and L_2 may be formed of glass, instead of plastic.

[0057] Wide-angle lenses according to the invention can be used not only in electronic still cameras and still cameras but also in cameras of any other type, for example, surveillance cameras (CCTVs).

[Brief Description of the Drawings]

[Fig. 1] A sectional view showing the wide-angle lens of Example 1 of the invention.

[Fig. 2] A sectional view showing the wide-angle lens of Example 2 of the invention.

[Fig. 3] A sectional view showing the wide-angle lens of Example 3 of the invention.

[Fig. 4] A sectional view showing the wide-angle lens of Example 4 of the invention.

[Fig. 5] Aberration diagrams of the wide-angle lens of Example 1 of the invention.

[Fig. 6] Aberration diagrams of the wide-angle lens of Example 2 of the invention.

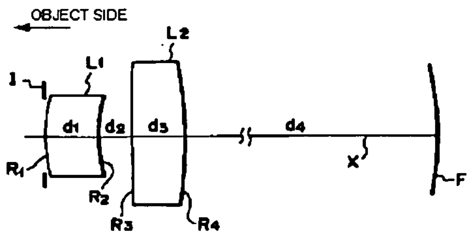
[Fig. 7] Aberration diagrams of the wide-angle lens of Example 3 of the invention.

[Fig. 8] Aberration diagrams of the wide-angle lens of Example 4 of the invention.

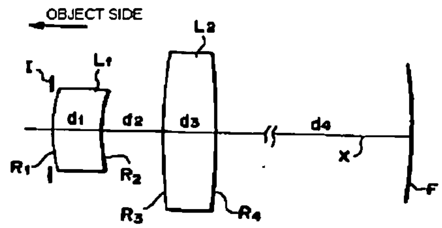
[Description of the Reference Designations]

L_1	First lens element
L_2	Second lens element
I	Aperture stop
F	Film
X	Optical axis

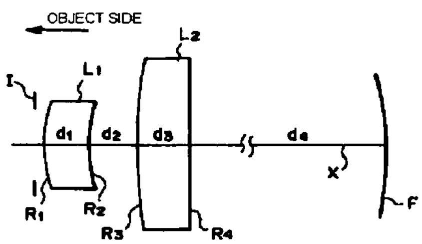
[Fig. 1]



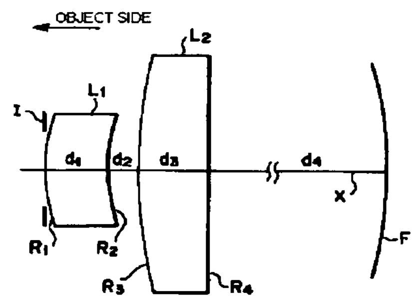
[Fig. 2]



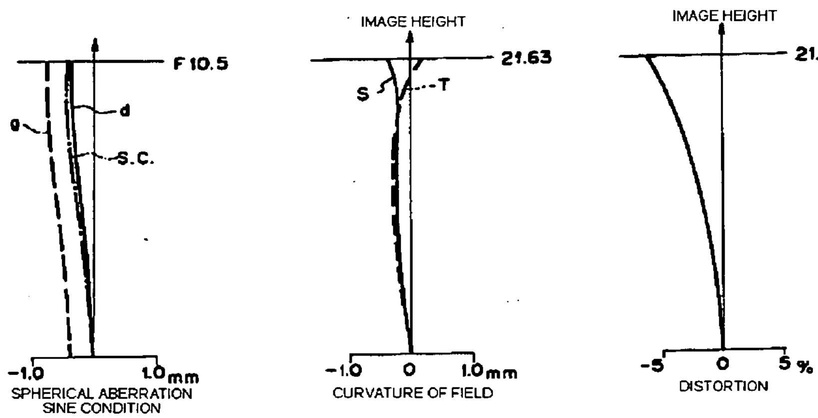
[Fig. 3]



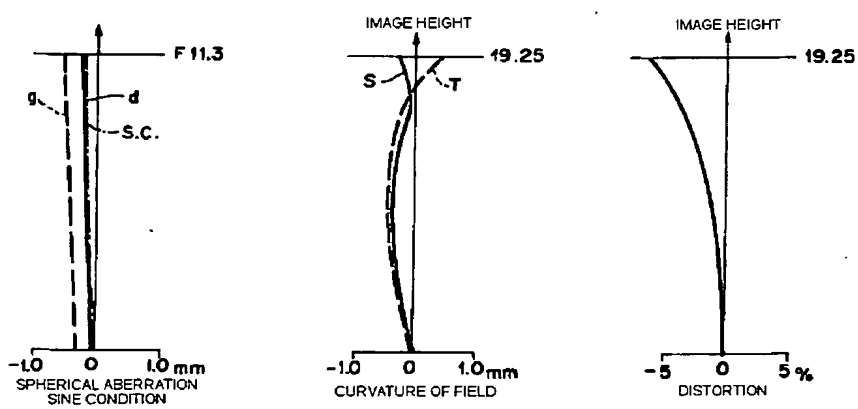
[Fig. 4]



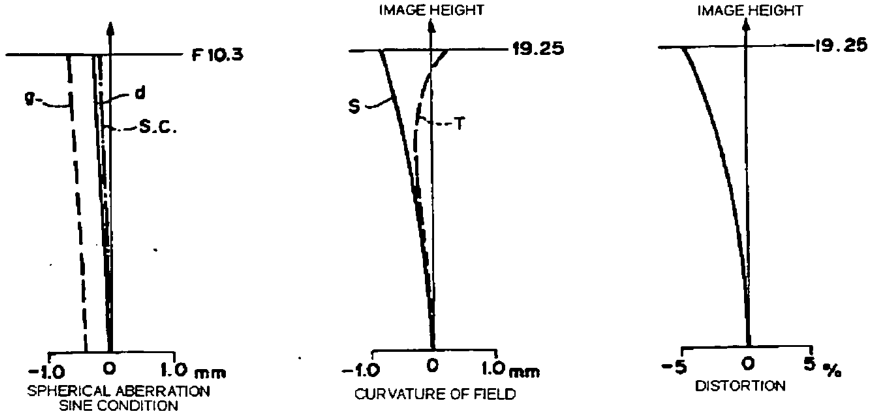
[Fig. 5]



[Fig. 6]



[Fig. 7]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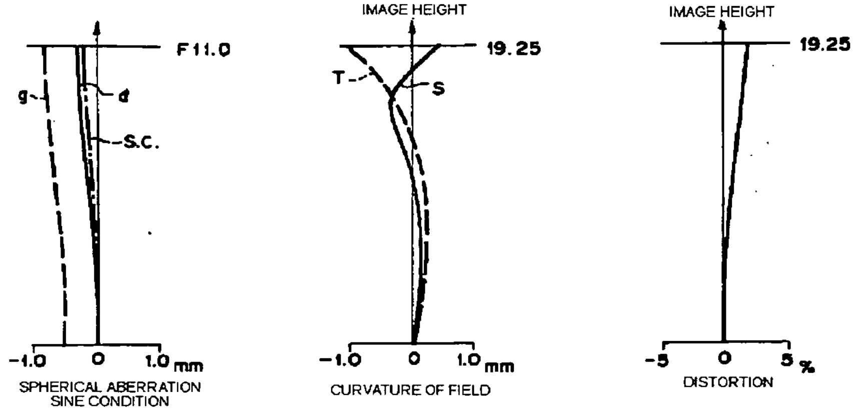
[Fig. 8]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G02B 9/04
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[Informality Amendment]
[Submitted on] December 27, 2001

[Amendment 1]
[Document to be Amended] Specification
[Item to be Amended] 0019
[Mode of Amendment] Replacement
[Amended Contents]

[0058] Conditional formula (4) noted above relates to the lens length. Transgressing the upper limit results in the second lens element L_2 having an unduly large external diameter, making it impossible to make the optical system compact. Transgressing the lower limit results in the first and second lens elements L_1 and L_2 having insufficient center thicknesses or in an insufficient distance between the first and second lens elements L_1 and L_2, and may result in insufficient correction of curvature of field.

[Amendment 2]
[Document to be Amended] Specification
[Item to be Amended] 0025
[Mode of Amendment] Replacement
[Amended Contents]

[0059]

[Table 1]

	Example 1	Example 2	Example 3	Example 4
f_2 / f_1	–0.0860	0.5051	0.5794	0.2933
f / R_1	6.1160	5.6995	5.8289	4.7367
f / R_3	0.1635	0.6673	1.4245	1.5070
D / f	0.1200	0.1842	0.1836	0.1950

L (mm)	33.471	26.011	25.245	24.417
L / f (telephoto ratio)	1.031	1.023	1.010	1.017

[Amendment 3]
[Document to be Amended] Specification
[Item to be Amended] 0031
[Mode of Amendment] Replacement
[Amended Contents]

[0060]

[Formula 1]

$$X = \frac{CY^2}{1+\sqrt{1-KC^2Y^2}} + a_4Y^4 + a_6Y^6 + a_8Y^8 + a_{10}Y^{10}$$